

The Practice of Informatics

Historical Perspectives ■

The Story Behind the Development of the First Whole-body Computerized Tomography Scanner as Told by Robert S. Ledley

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"The army called me down to New York [in 1950]. I was with New York University (NYU)—and the colonel said to me, 'Well, if you volunteer to be in the army, then you'll become a lieutenant, an officer. But if you don't volunteer, you'll be drafted anyway, and sent to boot camp. So I volunteered. And they sent me to medical field service school in Fort Sam Houston, Texas. And that was kind of interesting. And then, I guess my card dropped out, they wanted a dentist who was a physicist. And that was me.'"

Robert S. Ledley

Introduction

Dr. Robert S. Ledley is credited with "sowing the seeds" for the field of medical informatics [Ledley 1959],¹ initiating the development of computerized medical image analysis [Ledley 1964],² and for being the principal investigator of the Protein Information Resource (PIR) for 20 years [Dayhoff 1965].³ Dr. Ledley is best known for developing the first whole-body computerized tomography (CT or CAT) scanner in 1973 (Patent No. 3,922,552), which revolutionized diagnostic medicine. Dr. Ledley's first CT scanner [which he called the Automatic Computerized Transverse Axial, or ACTA, scanner; [Ledley 1974a, 1974b]^{2, 4} is now owned by the Smithsonian Institution's Museum of American History [Kondratas 2005].⁵ Using his scanner, he was the first to

perform three-dimensional reconstructions [Huang 1975],⁶ the first to use CT in radiation therapy planning for cancer patients [Scheer 1977],⁷ and the creator of many other "firsts" in the application of CT in medicine. The following story describes his efforts to develop this scanner.

How Did You Become a Dentist and a Physicist?

I always liked physics. I started at Columbia [University in 1942]. Once you're in the college, you can take any course in the whole university. In those days they only gave one year of college physics, and everything else was graduate physics. At Columbia, [graduate physics] was incredible. I had something like eight Nobel Prize winners as teachers. Hans A. Bethe,^a for example, came down from Ithaca and gave a course on atomic physics. It was absolutely incredible. And I had [Enrico] Fermi^b in thermodynamics. Yeah, it was a fantastic place. I received my masters' degree in [Theoretical] Physics in 1949.

Why Did You Then Go to Dental School?

I went to dental school because my father said, "You know, a physicist can't make a living, really. And the only thing you can do is be a poor professor. What you should do is become a dentist"—and we had a number of dentists in our family—"and then you can support your love of physics with your dentistry." And it turns out that I knew something about the history of physics. In the late 1800s and early 1900s, that's what was done. Most people supported their physics by doing other things.^c

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a. Hans Albrecht Bethe was awarded The Nobel Prize in Physics 1967 "for his contributions to the theory of nuclear reactions, especially his discoveries concerning the energy production in stars."

b. Enrico Fermi was awarded The Nobel Prize in Physics 1938 "for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons."

c. For example, Albert Einstein worked in a patent office in Switzerland from 1902 until 1909. In 1905, while working there, he earned a Ph.D. in Physics and published many important papers including: *Special Theory of Relativity*. (For more information on Albert Einstein see: <http://nobelprize.org/physics/laureates/1921/einstein-bio.html>.)

The only one who I knew who didn't do this was [Isidor Isaac] Rabi,^d and he was a professor and head of the physics department at Columbia. And he thought the idea that I was going to dental school at the same time I was taking graduate courses in physics was hysterical. It was the funniest thing he had ever known about. I graduated from Dental School in 1948, but I was too young to get a license. You had to be twenty-one to get a license.

A Financial Crisis Helps Focus One's Effort

I moved to Georgetown University in 1970. I moved the [National Biomedical Research] Foundation and everything, right in here, into these quarters [lower level of the medical library at Georgetown University]. And I had big grants from NIH. I had an engineering equipment grant, to build equipment that was required. And I also had a programming grant to do all the basic programming work that was required. And somebody said to me, "Why don't you put the two grants together, and it'd be a unified grant." Fine, okay, so I put them together—NIH, whatever they say, you do.

And then Nixon was president, and I get a call from NIH that the grants were approved, ready to be paid. This was in May. They were going to be paid in June. [Then] I get a call from NIH, "Nixon cut back the medical research funds"—"and we don't have the money to pay you." I had about, I don't know, forty, fifty people working. So I had to figure something quick!

So I talked to John Rose, hopefully my savior, and he said, "Wow. Well, you do scanning, right?" [RL:] "Yeah." He said, "Well, Dr. Luessenhop is interested in buying a scanner." So I went to see Dr. Luessenhop. Nice fellow, chief of Neurosurgery, but he was a brain surgeon. He says, "Well, I was going to buy this machine," and he shows me a slick brochure, the EMI machine [Hounsfield, 1976].⁸ It was a head scanner only. But what he didn't know is that they didn't have it yet. They just had a brochure!

So I looked at this book, and sure enough, you could see organs, but they were fuzzy. It was terrible; picture after picture. I didn't see how they could use much of that. But at the same time, I read a paper in *The Journal of Applied Physics*. It was written by a fellow by the name of Cormack at Tufts [Cormack 1963].⁹ And he took a cylinder of aluminum and a cylinder of wood, with a hole in it, that the aluminum fit into, and he scanned it, one scan. And he said, "Well, it's circular symmetric, so I'll make a whole lot of scans, because they're all the same." Okay? And then he worked out the absorption coefficient of the aluminum and the wood, to a very large number of significant figures. And I thought to myself, "Man! that's great! We can do it!" And I figured that I could make it.

So I went back to Dr. Luessenhop and I said, "I can make it, and it'll be half the price" [of that quoted for the EMI scanner]; I didn't even know what the price was!

It was a miserable machine. But I knew what to do. I was going to use convolution.^e How did I know that? Well,

Science magazine began putting pictures on their covers in the late '60s, I think. And they had a picture of a virus. They made the picture of the cross-section of a virus, and it looked kind of interesting. They took an electron microscope, and they scanned the virus right across. And then they couldn't really rotate it, so they said it's circularly symmetric, and they did what Cormack had done.

Anyway, what they did use was [convolution]. Great! People were talking about [convolutions] because you could take scratches out of pictures and things like that. So I figured, "That's it!" And I made a deal with the university. \$250,000 of the foundation's money, and we'll make Dr. Luessenhop a machine that can scan every place on the whole body. **A better one!**

Building the First Whole-body CT Scanner

Did You Know You Could Build It?

Well, I said I did. (laughter) If you haven't done it, you don't know if you can do it. So we went ahead. I had it designed in my mind, and I drew it on a paper, and we had a lot of cooperation. There was a machine shop—you can't believe it—in Georgetown, on Wisconsin Avenue, just below M Street. Can you imagine? A machine shop run by Allan Mitchell. And I went down, and this guy had a big lathe. Okay, great, so that's the guy. So I went to him, because he had a big lathe. I told him, "I'm making a medical machine." "Oh, you're making a medical machine? Oh, that's wonderful. I'd love to help you out." Of course, they charged, but still. And he said, "I've got one fellow, a young man I just hired, and he's very smart, very clever guy, and I'll put him on it, totally, he will be your machinist! He'll do nothing else." Because I knew it had a lot of parts.

Then I went around to get a mechanical engineer—couldn't get a mechanical engineer. I went to every engineering school in the region, and I couldn't get an engineer to do this for me. I could show the machinist what I wanted. So I figured, "Well, I've already spent two weeks on this, going around. Forget it, I'll do it myself." After all, I had had a course in engineering mechanics. So I designed every detail in it myself. There isn't a thing that I learned that I didn't use.

So I sat down and designed it in detail. I also had a great electronic engineer, Tom Golab, and a great programmer/mathematician, James Wilson. And what I did was, I drew a sort of three-dimensional picture to show what each part was, and then I made the ordinary mechanical engineering drawings [See Fig. 1 for a copy of the mechanical drawing included in the original patent application]. And this fellow, Frank Rabbitt was his name, and he was great. He had all the sense that was required. So I drew him the pictures, and we'd leave them under the door at about eleven in the evening. It was an around-the-clock job. And then in the morning he'd study the plans when he came in at six in the morning, and he would call me up and say, "Do you really

d. Isidor Isaac Rabi was awarded The Nobel Prize in Physics 1944 "for his resonance method for recording the magnetic properties of atomic nuclei."

e. Convolution is a mathematical operator which takes two func-

tions f and g and produces a third function that in a sense represents the amount of overlap between f and a reversed and translated version of g . A convolution is a kind of very general moving average, as one can see by taking one of the functions to be an indicator function of an interval. [from: <http://en.wikipedia.org/wiki/Convolution>]

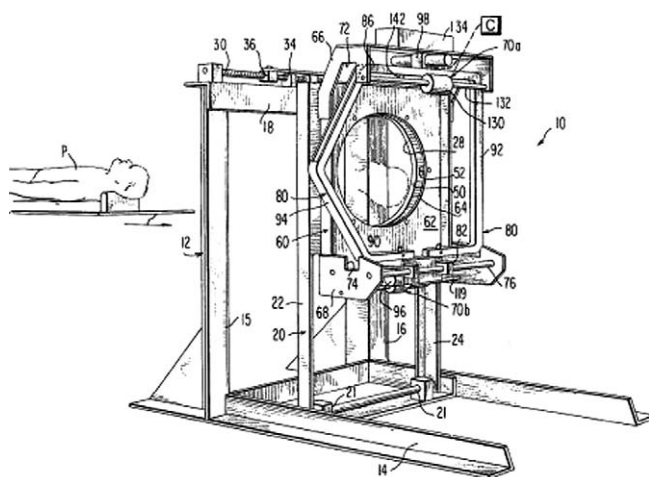


Figure 1. Mechanical drawing of the ACTA scanner from Dr. Ledley's patent.

mean you want the hole here? And which hole is it going to be attached to? Are you sure?" And I looked at it, sure enough, he was right. You've got a figure that's off slightly he'd say. He was a great guy, and I hired him afterwards. But he never had any engineering training, but he had the engineering sense.

So I decided to use cold-rolled steel; that was the strongest material for its weight [at that time]. So I found out about that, and I [went to] take a look at a piece of cold-rolled steel. It looked terrible! It was blotchy, looked like it was rusty, but it wasn't rusty. And I decided the doctors would never go along with that. It's got to look pretty. So Capital Cadillac in those days was down here. So I figured, well, car places have paint shops. So I go down to Capital Cadillac and I say, "I'm making this medical machine." "Oh! You're making a medical machine? We'd love to help you out." So I said, "Cold-rolled steel looks terrible, and I need it painted before it comes here, right from the machine shop." He said, "I have the ideal person. I'll put him totally on your job." And it was a man, who was ready to retire, but he still had time to go, another six months or so, and he said, "This fellow is a detail man. He'll do the greatest paint job. I hate to give him big jobs, because he can't carry things. He's an older guy." So that's what I did. So I designed the parts at Georgetown University, I went to Allan Mitchell, they machined it. And the fellow took it over to Capital Cadillac. He was supposed to call me when he got it, which he did, and then he painted it, and then we brought it back. I don't remember whether he brought it, or we went over there to get it. And all I had to do was ream out the threads, because he painted everything. So that's how we made it. That's what we did. And it was a resounding success.^f [See Figs. 2 and 3.]

What Did That Feel Like For You?

Oh! it feels so great. I gave a lecture the other day at the hospital over in Virginia—Fairfax Hospital. I gave this lecture on something about the history, this kind of thing,

f. The ACTA scanner went into routine clinical use at the Georgetown University Medical Center at the end of February 1974 [Schellinger, 1975].¹²



Figure 2. The 0100 ACTA Scanner (which stands for automated, computerized, transverse axial scanner) is the world's first whole-body scanner.

telling these stories. And a lady stands up and says to me, "You know, I'm walking because of you. I had a bad disease, and it was diagnosed by one of your machines. I'm a nurse now. I am always on my feet, and I always have to walk around. And if they didn't make the diagnosis, I wouldn't be walking today." So that's the reward, when you really get down to it.

The Scanner Saves a Life

I'll tell you the story of my first life-saving. We were fixing up the machine and making it a little better, this, that, and



Figure 3. The computer used to run the ACTA Scanner.

the other, and Dr. Luessenhop comes in the room, and he looks at the pictures that I made, there were no CT phantoms. You know what a phantom is—a model that you make. They were models that generally were exactly like what you were going to take X-rays of—to see whether something worked—that was the purpose of the model. I figured the hardest thing was going to be the brain. And what I used was the skull, a real skull that I had when I went to school. I took a course in gross anatomy, had to have a real skull. Nowadays, you don't have to have a real skull, but you did then. And in those days there were butchers, and I had delivered to the university, every day, fresh calf's brains. Calf's brains were a delicacy in those days. What were they called—[sweetbreads]? And then I put the calf's brains in the skull, and put test tubes of water in for the ventricles, and scanned them. That was my Phantom. So he said, "That's good enough. I'm bringing down a patient." This couldn't be done today [because of the Institutional Review Board procedures]!

So we scanned a patient, and that was the beginning. Now, after about two weeks, there was a pediatric neurosurgeon, Dr. McCulloch. I got to know all the neurosurgeons. And he says to me on a Monday morning, "Did you hear about the wonderful case we had?" So I said, "Well, I'm sure I heard about it, because I must have seen it, because I haven't walked away from that computer." I was there eight hours a day with that machine. I couldn't get myself to walk away. It was built into the room in which it was going to be used, and I couldn't get myself to walk away from it. I just couldn't walk away. So he said, "Well, we had a four-year-old boy who fell off a bike and hurt his head. Nobody saw him fall, but the parents took him to a pediatrician. He was kind of groggy, and the pediatrician brought him into the emergency room." This is what Dr. McCulloch is telling. And he says, "So I happened to be in the emergency room at the time. So I looked at the kid, and I thought to myself, 'You know, I think we ought to scan him.' So I took him upstairs and I scanned him." So I said, "Well, who ran the machine? Because I didn't see any four-year-old boy. There wasn't any four-year-old boy. What are you telling me about?" I stood there every day, eight hours a day, I was standing there, all the time the machine was being used. So I said, "Who ran the machine?" He said, "I did." I said, "You did?! How'd you know what to do?" And he says, "I watched the tech do it. I've seen it." I said, "And you just knew how to use the machine?" He says, "Yeah! And there was a bleed. And I took him down to Surgery and took out the blood, and you saved his life." It was incredible! He said, "If I'd waited till Monday, then it would have been over, the kid would have been dead." That was it. Can you imagine that? That was our first save. And I thought to myself, "What am I standing around for? This neurosurgeon just watched and he could run the machine. I don't have to watch!"

[This happened] over and over again, and I was inducted into the National Inventors Hall of Fame. And they had a banquet at the museum. There were ten people at each big round table. After dinner, this lady comes over to me, and she gives me a big bear hug. I mean, she was big herself, she was tall. So I said, "Now, what did I do to deserve that?" And she says, "You saved my daughter's life." So that's what makes it worthwhile.

Commercializing the Scanner

So have you licensed the patent [for the CT scanner] to other companies?

Well, I started my own company to make the scanners. I was manufacturing the scanners.

Down in the Shop and at the Cadillac Dealership, Or Did You Have Someone Else By Then?

(laughter)

Well, it was almost that bad. The vice-president in charge of the medical center, a fellow by the name of Matt McNulty—he passed away—but he comes down one day and says, "A lot of people want this thing, don't they?" [He meant] radiologists. I said, "Oh, yeah!" He says, "Well, you really can't go into business in the basement here." I said, "Yeah, I know." So he says, "Why don't you just form a profit-making company and bill them?" I said, "Okay, I'll do that." So I did, I formed a company called DISCO, Digital Information Science Corporation.⁸

And when Disco was about four or five years old, it was difficult to fill all the orders. Not only that, but there was no venture capital in those days, no new venture capital. And somebody says to me, "Well, you go to the bank and you borrow money." Okay, so I go to the bank, and I tell the guy I want to borrow money. And I've already told him all the things I'm doing. And he says to me, "Could you tell me again exactly what you're doing?" So I tell him again, and he says, "Well, we actually only fund builders who build houses." So I figured enough of that, I'm wasting my time.

So I said to the radiologists when they wanted one, "Look, it costs \$300,000"—of course the university only paid me \$250,000. So I had to build them—" \$300,000 with \$100,000 in advance. And then when I'm half finished, another \$100,000. [Then] when I deliver it, the rest." That's the way I did it. That was the business. From the time we got the order to the time we delivered, it was about three months. I hired all the people. That's the math. Now, what happened after a couple of years, I decided I've got to sell this company, I mean, this is too much.

One of the problems was, the \$100,000 in advance. That bothered the heck out of me, because I absolutely had to build that machine for whoever gave me \$100,000, come hell or high water. And that's what I'm going to do. Wasn't any question about it, I've got to deliver. People that give me \$100,000 for it, they're going to get their money's worth. They're going to get it. And that kept me up at night. It was a big company. We had a hundred or more people. And then I had a system whereby I delivered the parts to the Radiologists room in which it was to be made. Well, first of all, they had to prepare their rooms. And then I sent around an inspector to make sure that they prepared the rooms correctly. It had to have water to heat the oil—it's an oil to water heat exchanger. They had to have the right current and voltage and everything. There was a lot to do.

What I didn't realize was that these people made this a center of attraction of their facility. I didn't realize that until I went to one place, the first one. It was in Minnesota, in

g. R.S. Ledley served as President & CEO of Digital Information Science Corporation from 1969 to 1975.

Minneapolis. I said, "Do you have your room prepared?" And he said, "Yeah, I have it all prepared," and he takes me to the room. "You want to see it?" I walk in, and it had birch paneling. Incredible! It was gorgeous! Even here at Georgetown, they had the nicest wallpaper that you ever saw. It was fancy, beautiful flowers.

So that was a real good machine [Ledley 1974c].¹⁰

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APPENDIX: A SHORT BIOGRAPHY OF ROBERT S. LEDLEY

Dr. Ledley was born in Flushing Meadows, NY in 1926. He holds a Master's degree (1949) in theoretical physics and mathematics from Columbia University and earned a D.D.S. from the New York University College of Dentistry in 1948. In addition to the ACTA scanner, Dr. Ledley patented the first special purpose image processor called the TEXAC, invented the AZOR (Automatic Zone Reorder) for antibiotic quality control testing used by the FDA and many drug companies, and constructed one of the first digital subtraction fluorographic machines. He wrote the first comprehensive textbook for engineers on digital computer engineering, and developed computational methods in Boolean logic

used extensively for digital circuit design. He was inducted into the National Inventors Hall of Fame in 1990 for his invention of the first body CT scanner, and is a member of the Institute of Medicine for the National Academy of Sciences. In 1997, he was awarded the National Medal of Technology by President William Jefferson Clinton. He was a founding fellow of the American College of Medical Informatics, and was awarded the Morris E. Collen medal in 1998 by the College [Broering, 1999].¹¹

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Ledley, R.S., Huang, H.K. and Mazziotta, J.C. (1977) Cross-Sectional Anatomy: An Atlas for Computerized Tomography. Baltimore MD: Williams and Wilkins Co.

Founder and Editor-in-Chief of the Peer-Reviewed Scientific Journals:

Pattern Recognition, Elsevier Science, Oxford, England

Computers in Biology and Medicine, Elsevier Science, Oxford, England

Computerized Medical Imaging and Graphics, Elsevier Science, Oxford, England

Computer Languages, Systems and Structures, Elsevier Science, Oxford, England

Selected Patents Awarded:

Separation of Fetal Cells from Maternal Blood, #5,639,669; Diagnostic X-Ray System, #3,922,552 (the first whole-body computerized tomograph); Method and System for Whole-Picture Image Processing, #4,229,797 (the first special purpose image processing computer); Ultrasonic Scanner, #4,271,706; Microfocus X-ray Tube, #4,281,269; Digital Fluorographic Method and System, #4,450,478; Split-Image, Multi-Power Microscopic Image Display System & Method, #4,651,200; Interactive Microscopic Image Display System & Method, #4,769,698; 3-D Imaging System, #4,821,728; 3-D Cursor Control Device (BAT), #5,296,846

In addition, Dr. Ledley has authored or co-authored over 300 peer-reviewed scientific articles.